"Acoustic Characterization of Bunker 1201", Group II: Security-Related Research and Methodology

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Acoustic Characterization of Bunker 1201

Introduction

Less-than-Lethal Technologies are of interest to the Military, Department of Justice, as well as Other Agencies dealing with barrier/delay facility protection systems. There is a myriad of potential Users, such as: Law Enforcement, Bureau of Prisons, and other government agencies, all of which face long-term guard or security force mortgages for facility control or protection. Initial investment and installation of Non-Lethal Directed Energy Devices provides one alternative to shedding these long-term commitments in an effective fashion.

By utilizing Directed Energy Technologies, the need for cost effective facility barrier/delay can be satisfied. One of the possible solutions to this problem can be either the use of acoustic energy or the combination of acoustic energy with light and smoke. Over the last 15 years, considerable efforts have been extended in the area of both acoustics and flashing light. The type(s) of physiological expected effects can range from disorientation to even lethality. These alterable, or agile, types effect(s) can be utilized to provide tunable results - based upon the operational protection scenarios and requirements of the various User organizations.

The experimental and analytical results reported in this paper, work towards the establishment of a method useful in the design of a facility acoustic protection scheme. This facility characterization was an exercise in studying the interactions between acoustic energy and an enclosed facility, i.e. a bunker enclosure, as well as management of digital data recording and follow-on data reduction and analysis. Physical acoustic parameters were explored including sound pressure level field mapping, volume resonance, structure resonance, reverberation time, absorption coefficient and symmetry. Supporting Finite Element Analyses (FEA) were also performed. These results indicated that FEA methods could be useful as a predictive tool in the design and characterization of an acoustic protection scheme for a facility and expedite the total process, which could result in considerable cost reduction in Facility Characterization.

Approach

A dual approach, experimental and analytical, was used in establishing a facility/room characterization scheme.

Experimental:

> The experimental method explored physical acoustic characteristics that included: sound pressure level field mapping, volume resonance, structure resonance, reverberation time, absorption coefficient(s), and symmetry response.

Figure 1 is a photograph of the exterior of Bunker 1201. The basic structure is reinforced concrete with a soil berm on three sides. Figure 2 is a photograph of the structure's interior. This depicts the concrete floor, walls, and ceiling; it also indicates the position of the acoustic sources, and instrumentation that was used in this portion of the study. (An idea of microphone placement can be gathered by looking ahead to the Results - Figure 4.)

The following initial, multi-phase testing matrix served the purpose of establishing a viable method of building/room characterization that would be useful in the design of a facility acoustic protection scheme.

- Basic Field Plot of White Noise Source (22-250Hz): Mapped acoustic intensity outside Bunker 1201 for both white noise and various discrete frequencies.

- Bunker 1201 Characterization: Acoustic mapping of intensity inside Bunker 1201 for both white noise and various discrete frequencies. Obtain reverberation time of Bunker 1201 for both white noise and various discrete frequencies. Calculate absorption coefficient(s) for Bunker 1201 surface(s). Obtain resonant frequency of Bunker 1201 volume and structure.

Analytical:

The analytical method was to establish a predictive technique determining, similar to the experimental approach, the physical acoustic characteristics of Bunker 1201 and to benchmark this method against the field results.   Once again, that included sound pressure level field mapping, volume resonance, and structure resonance.

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- 3/D model assembly. Including accurate representation of the structure's geometry-symmetry was assumed in assembling the model- and material(s), boundary conditions, real constants-e.g. absorption coefficients, and accurately modeling the acoustic sources-matching experimental sources. Figure 3 shows the 3/D model that was assembled for the purpose of these analyses. For clarity purposes the soil and air are not shown.

The analytical method predicted room harmonic sound pressures for various energy levels at discrete frequencies ranging between 30-to-250 Hz and was benchmarked against the experimental results.

Results

A brief discussion of selected experimental and analytical results, along with a comparison of techniques follows.

Experimental:

This portion of the study produced a number of results. These included: the reverberation time, average absorption coefficient, structural resonant frequencies, symmetry verification, comparison of acoustic parameters obtained via white noise or discrete frequency, and acoustic mapping of pressure fields from white noise/discrete frequency sources. For the purpose of this paper, the discussion of results is limited to acoustical mapping. An experimentally generated acoustic intensity map is shown in Figure 4. This is the result of multiple microphone readings, as well as management of digital data recording and follow-on data reduction and analysis.

Analytical:

Again, for the purpose of this paper, this portion of the discussion is limited to the harmonic sound pressure distribution. The volume resonant frequencies, structural resonant frequencies, transient response, and harmonic sound pressure distributions at other frequencies were also determined. A typical analytical prediction of a harmonic sound pressure distribution is shown in Figure 5.

Comparison:

Significant time and money was spent in taking the experimental data and the follow-on data reduction that was required. If an analytical technique could be established that would replicate or predict a portion of the results of the field testing, a great deal of savings would result. Although, the authors are not suggesting that computer modeling would completely eliminate the need for these tests, the tests could be substantially reduced in scope. Figures 6a-b contain one comparison of the two techniques at a vertical distance of 3’ and 6’, respectively. As the figure indicates, the analytical results for a 31.5 Hz harmonic source compare well with experimental data taken at the bunker measurement points and can be used to predict the overall form of the sound pressure field. Furthermore, the analytical model was able to characterize the sound pressure field for higher frequencies, which would require significantly more data points, if done experimentally.

Summary/Conclusions/Recommendations

A dual experimental and analytical approach was taken in determining the acoustic characteristics of Bunker 1201. Experimental investigations included generating physical acoustic characteristics-including sound pressure level field mapping, volume and structure resonance, reverberation time, absorption coefficient(s), and a check of Bunker 1201 symmetry response. The analytical investigation accurately predicted volume resonance, structural resonance, and generated comparable field maps at the discrete test frequencies. The analytical techniques will not completely replace the experimental, but future facility characterization efforts should involve a combined analytical-experimental approach. This will help ensure a timely, cost effective solution to implementing facility barrier/delay design.

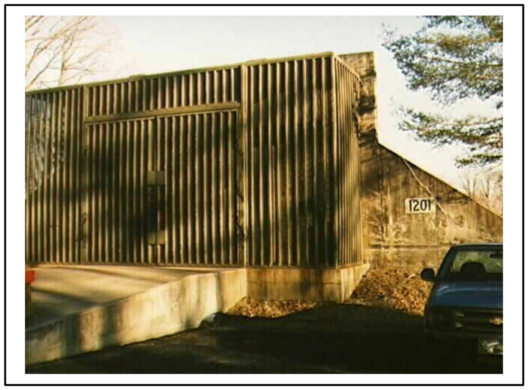

Figure 1. Photograph of Bunker 1201 Exterior

Figure 2. Photograph of Bunker 1201 Interior: Construction, Sources, and Instrumentation

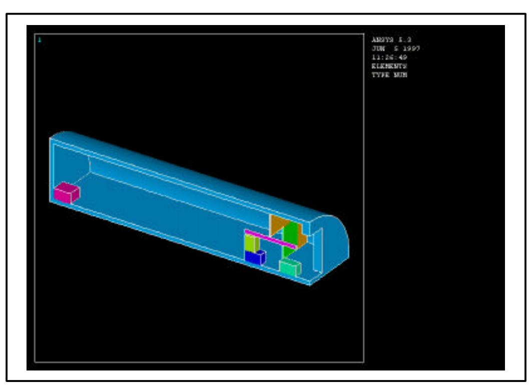

Figure 3. Analytical Representation of Bunker 1201

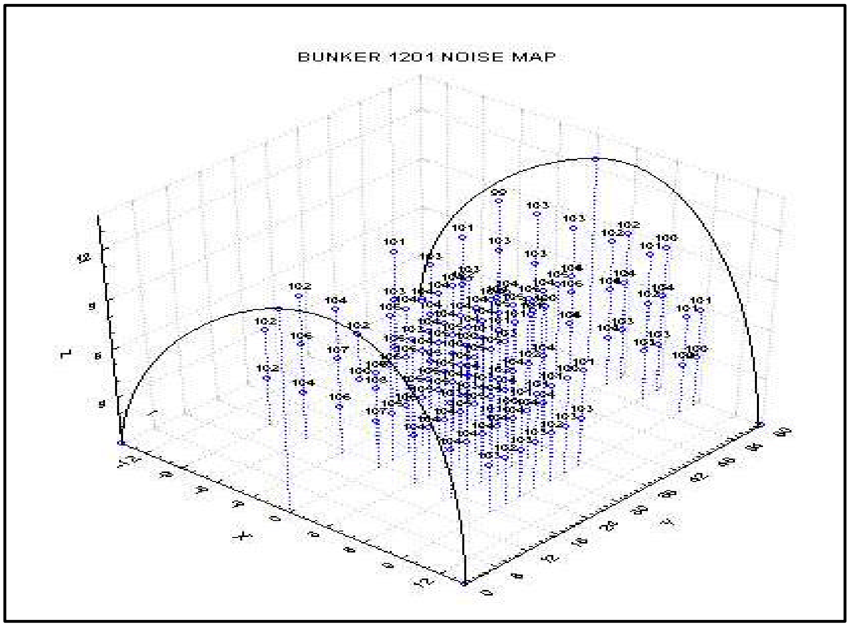

Figure 4. Experimentally Generated Acoustic Intensity Map

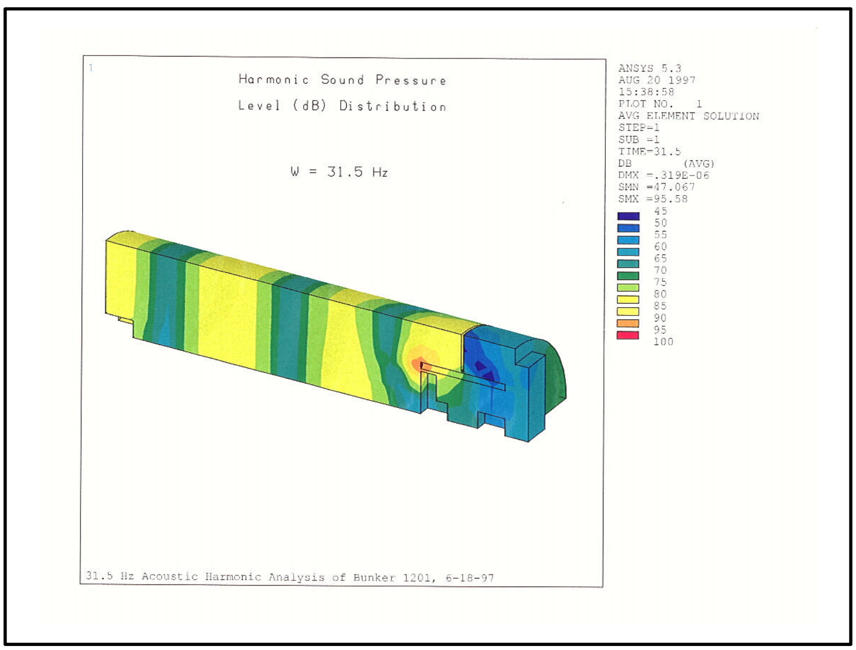

Figure 5. Analytical prediction of Harmonic Sound Pressure Distribution

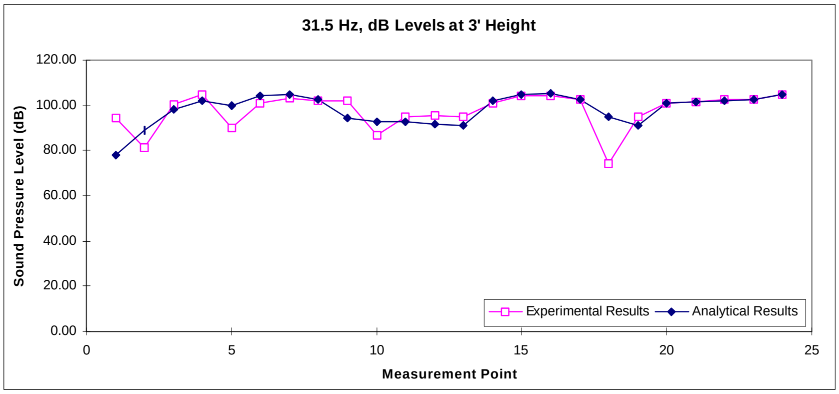

Figure 6a. 2/D Line Comparison of Experimental and Analytical Results @ 3' Height

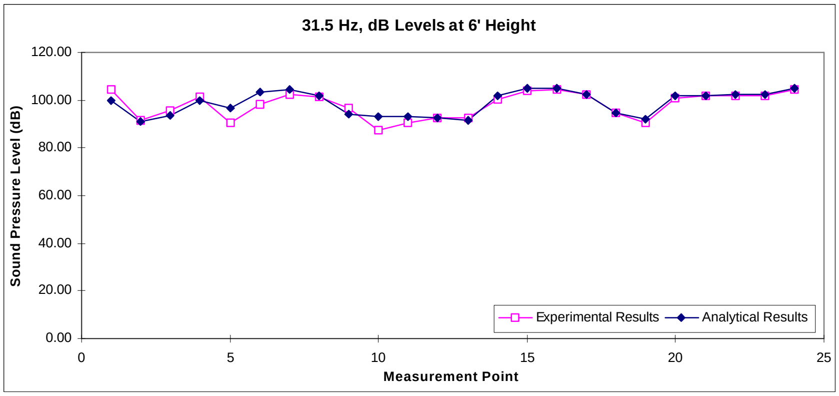

Figure 6b. 2/D Line Comparison of Experimental and Analytical Results @ 6' Height